PATENT ABSTRACTS OF JAPAN

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(54) **ELASTIC BOUNDARY WAVE ELEMENT**

(57)Abstract:

PROBLEM TO BE SOLVED: To facilitate characteristic designs and production and to obtain a stable characteristic by forming a comb-line electrode at recessed parts which are periodically provided on a main surface of one piezoelectric material single-crystal substrate, performing cleaning and hydrophilic processing of the surfaces of two substrates as an interface, overlapping them, performing heat processing and directly bonding them on an atomic level.

SOLUTION: After a piezoelectric material single-crystal substrate 11 is cleaned, a photoresist mask is formed and performed etching, and a metallic film is formed on a plane on which recessed parts are periodically formed with vacuum deposition. Next, a metallic film except the photoresist mask and the recessed parts is eliminated, the metallic film remains only at the recessed parts, and comb-line electrodes 13, 13', 14 and 14' are formed. After that, piezoelectric material single-crystal substrates 11 and 12 are overlapped and undergo thermal processing at about 200°C for ten hours after their surfaces are cleaned, and hydrophilic processing is performed. As a result, bonding that is related to oxygen, hydrogen and substrate component atoms proceeds from the bonding of hydrogen bonding subjects of a hydroxyl group and bonding is strengthened. This improves a piezoelectric and elastic quality and increases the degrees of freedom for designing.

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CLAIMS

[Claim(s)]

[Claim 1] It consists of the 1st substrate, the 2nd substrate, and a Kushigata electrode for exciting an elastic wave. One [at least] substrate of said 1st and 2nd substrates is a piezo electric crystal single crystal. And said Kushigata

electrode is formed in the crevice where one [at least] substrate was periodically formed on the principal plane on the other hand. The elastic boundary wave component characterized by joining directly the substrate front face which turns into said the 1st and junction interface of said 2nd substrate so that the field in which said Kushigata electrode was formed may turn into an interface on atomic level defecation and by carrying out hydrophilization processing and carrying out superposition heat treatment.

[Claim 2] The elastic boundary wave component according to claim 1 characterized by all the aforementioned substrates being piezo electric crystal single crystals.

[Claim 3] The elastic boundary wave component according to claim 1 or 2 characterized by choosing at least one substrate from the matter which uses silicon, oxidation silicon, and oxidation silicon as a principal component among the aforementioned 1st and the 2nd aforementioned substrate.

[Claim 4] The 1st substrate, the 2nd substrate, and the 3rd substrate pinched by said 1st substrate and 2nd substrate, It consists of a Kushigata electrode for exciting an elastic wave, and at least one substrate of said 1st, 2nd, and 3rd substrates is a piezo electric crystal single crystal. And said Kushigata electrode is formed in the crevice of at least one substrate formed on the principal plane on the other hand. The elastic boundary wave component characterized by joining directly the substrate front face which turns into a junction interface of said 1st, 2nd, and 3rd substrates so that the field in which said Kushigata electrode was formed may turn into at least one interface on atomic level defecation and by carrying out hydrophilization processing and carrying out superposition heat treatment.

[Claim 5] The elastic boundary wave component according to claim 4 characterized by all the aforementioned substrates being piezo electric crystal single crystals.

[Claim 6] The elastic boundary wave component according to claim 4 or 5 characterized by choosing at least one substrate from the matter which uses

silicon, oxidation silicon, and oxidation silicon as a principal component among the 1st, 2nd, and 3rd aforementioned substrates.

[Claim 7] An elastic boundary wave component given in either of claims 1-6 characterized by being the alloy with which the Kushigata electrode uses gold as a principal component.

[Claim 8] An elastic boundary wave component given in either of claims 1-7 characterized by forming a protective layer in the Kushigata electrode.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[Field of the Invention] This invention relates to the elastic boundary wave component used for a filter, a resonator, etc.

[0002]

[Description of the Prior Art] In recent years, small [of communication equipment], a light weight, and high performance-ization are progressing by advance development of mobile communication technology. An oscillator and a high pass filter are surely required for these devices, and small, a light weight,

and high performance-ization are called for also from these oscillators and high pass filters. The surface acoustic element has been conventionally used for these oscillators and high pass filters widely. A surface acoustic element is a device with which an elastic wave mainly spreads a solid-state front face. Therefore, the condition of a solid-state front face and its near affects the propagation property of a surface acoustic wave greatly. The gas near [which an elastic wave specifically spreads] the solid-state front face, a steam, etc. affect it. Therefore, space needed to be held on the substrate front face which an elastic wave spreads, for example, the surface acoustic element was put into the package, it was filled up with inert gas, and the closure was performed. Thus, a package is required for a surface acoustic element, and the magnitude of an oscillator or a high pass filter is decided by magnitude of a package. Therefore, there was a limitation in the miniaturization of an oscillator or a high pass filter, and lightweight-ization.

[0003] There is an elastic boundary wave component to solve the above-mentioned problem. An elastic boundary wave component is a device with which energy is centralized on the interface to which two solid-states were joined, and an elastic wave mainly spreads a junction interface. Since the interface has not exposed the elastic boundary wave component, the miniaturization and lightweight-izing of an oscillator or a high pass filter of a package are attained unnecessarily therefore. With the conventional elastic boundary wave component, for example, an elastic boundary wave filter and an elastic boundary wave resonator, after forming the Kushigata electrode in a piezo-electric substrate, a non-piezo-electricity layer is formed by the forming-membranes methods, such as a spatter. Or after forming the Kushigata electrode in a non-piezo-electricity substrate, a piezo-electric layer is formed by the forming-membranes methods, such as a spatter, and a non-piezo-electricity layer is further formed in said piezo-electric layer by approaches, such as a spatter. The elastic boundary wave is excited by adding an alternating electric field to said electrode (the Japan Society for the Promotion of Science surface acoustic element technical 150th

time [9th] committee study materials, pp.17-22). The conventional elastic boundary wave component is explained below. Drawing 11 shows the conventional elastic boundary wave component. An elastic boundary wave component is constituted using the piezo electric crystal substrate 71, the non-piezo electric crystal layer 72, the Kushigata electrodes 73 and 74, 73', and 74'. The Kushigata electrodes 73 and 74, 73', and 74' are formed on the piezo electric crystal substrate 71, and the non-piezo electric crystal layer 72 is formed by the forming-membranes methods, such as a spatter, on an electrode forming face.

[0004]

[Problem(s) to be Solved by the Invention] The above-mentioned elastic boundary wave device forms a laminated structure using a thin film process. In this case, a limit is received in the combination of a substrate and a film ingredient. For example, when choosing a piezo electric crystal as a film ingredient, in order to take out a piezo-electric property, it is required to make an one direction arrange and carry out orientation of the crystal orientation at least, but in order to carry out orientation, the combination of a substrate and a film ingredient is limited extremely. Moreover, the membranous direction of orientation is also limited. Moreover, the piezoelectric film formed by sputtering etc. has large dispersion in an elastic property, and a piezo-electric property is inferior in it compared with a bulk single crystal. Although it is desirable to form a piezo-electric single crystal thin film with an epitaxial growth technique desirably, the substrate which can do epitaxial growth is restricted and the combination of a substrate and a film ingredient is limited further. Moreover, although the laminated structure by the substrate of arbitration and the combination of a piezo electric crystal is called for in order to correspond to the elastic boundary wave component of various applications, by the approach by the conventional membrane formation, combination is limited extremely. Moreover, in a thin film process, since substrate heating is required, residual stress poses a problem. When stress remains too much in a substrate cooling process, specifically, a

substrate may be destroyed. Even when not resulting in substrate destruction, curvature arises in a substrate, and it becomes the cause of fault in using a photolithography for a process. Moreover, although the substrate thickness of extent whose variation rate of an elastic boundary wave is substantially lost in a laminated-circuit-board front face was required for the elastic boundary wave component, when based on membrane formation, deposition of the film of sufficient thickness took time amount, and there was a problem practically. Moreover, when adhesives are used as a means of a laminating, there is a limit in the thinness of a glue line and it is still more difficult to make thickness of a glue line into homogeneity. Moreover, in a glue line, an elastic boundary wave is decreased remarkably, and a desirable property is not acquired. Moreover, the elastic property of a glue line also changes with time amount. The purpose of this invention makes it possible to realize the laminated structure in the bulk substrate ingredient of arbitration without a glue line, and to form the Kushigata electrode in an interface, and a property design and manufacture are easy for it, and it is offering the elastic boundary wave component by which the property's was stabilized.

[0005]

[Means for Solving the Problem] The 1st elastic boundary wave component of this invention consists of the 1st substrate, the 2nd substrate, and a Kushigata electrode for exciting an elastic wave. One [at least] substrate of said 1st and 2nd substrates is a piezo electric crystal single crystal, and said Kushigata electrode is formed in the crevice where one [at least] substrate was periodically formed on the principal plane on the other hand. Said the 1st and said 2nd substrate are directly joined so that the field in which said Kushigata electrode was formed may turn into an interface. Direct junction is defecation and junction of the atomic level which carried out hydrophilization processing and minded the oxygen atom according the substrate front face used as a junction interface to carrying out superposition heat treatment. In this structure, it is characterized by an elastic wave mainly spreading the junction interface of said 1st substrate and

said 2nd substrate. By taking such a configuration, it excels in a piezo-electric property and the degree of freedom of a design can offer a large elastic boundary wave component. Moreover, the 2nd elastic boundary wave component of this invention consists of the 1st substrate, the 2nd substrate, the 3rd substrate pinched by said 1st substrate and 2nd substrate, and a Kushigata electrode for exciting an elastic wave. At least one substrate of said 1st and 2nd, and 3rd substrate is a piezo electric crystal single crystal, and said Kushigata electrode is formed in the crevice where at least one substrate was periodically formed on the principal plane on the other hand. As the field in which said Kushigata electrode was formed for said 1st and 2nd, and 3rd substrate turns into an interface, it is joined directly mutually. Direct junction is defecation and junction of the atomic level which carried out hydrophilization processing and minded the oxygen atom according the substrate front face used as a junction interface to carrying out superposition heat treatment. In this structure, it is characterized by an elastic wave mainly spreading said 3rd substrate. By taking such a configuration, it excels in a piezo-electric property and the degree of freedom of a design can offer a large elastic boundary wave component. Moreover, said all substrates may be piezo electric crystal single crystals. Moreover, said at least one substrate may be chosen from the matter which uses silicon, oxidation silicon, and oxidation silicon as a principal component. Moreover, said Kushigata electrode may be the alloy which uses gold as a principal component. Moreover, the protective layer may be formed in said Kushigata electrode.

[0006]

[Embodiment of the Invention] Hereafter, it explains to a detail, referring to an attached drawing about the gestalt of operation of this invention.

(Gestalt 1 of operation) Drawing 1 is 1 section notching perspective view of the gestalt of operation of the 1st of the elastic boundary wave component of this invention, and drawing 2 is a sectional view in the a-a' section of drawing 1 . The elastic boundary wave component shown in drawing 1 and drawing 2 is constituted using the piezo electric crystal single crystal substrate 11, the piezo

electric crystal single crystal substrate 12, the Kushigata electrodes 13 and 14, 13', and 14'. The crevice is formed in the plane of composition of one piezo electric crystal single crystal substrate 11 with the predetermined period, and the Kushigata electrodes 13 and 14, 13', and 14' are formed in said crevice. In the device which drawing 3 R> 3 shows the piezo electric crystal single crystal substrate 11 and the piezo electric crystal single crystal substrate 12, respectively, and is shown in drawing 1 and drawing 2 , the piezo electric crystal single crystal substrate 11 and the piezo electric crystal single crystal substrate 12 are laminated without adhesives by direct junction. In addition, although one [at least] substrate of the 1st and 2nd substrates 11 and 12 should just be a piezo electric crystal single crystal, with this operation gestalt, both substrates are single crystal substrates. By impressing an alternating electric field to the Kushigata electrodes 13 and 14, an elastic boundary wave is excited and an elastic boundary wave spreads the actuation as an elastic boundary wave component in accordance with the interface between both the piezo electric crystal substrates 11 and 12. This elastic boundary wave is again changed into an electrical signal by Kushigata electrode 13' and 14'. In addition, although the basic configuration of the elastic boundary wave which used the Kushigata electrode is shown in drawing 1 and drawing 2 , in making it a filter and a resonator, it changes the number and configuration of the Kushigata electrode if needed.

[0007] Formation of the Kushigata electrode and direct junction are large, and the manufacture process of this elastic boundary wave component is divided into two processes. Formation of the Kushigata electrode is explained first. A procedure is shown for the method of forming the Kushigata electrode in drawing 4 later on. After washing the piezo electric crystal single crystal substrate 11 first, the photoresist mask 15 is formed (a). Next, the substrate side 11 in which the photoresist mask 15 was formed is etched in a fluoric acid system water solution, and a crevice is formed periodically (b). Next, a metal membrane 16 is formed in the field in which the crevice was formed, with a vacuum deposition method (c).

The desirable thing equivalent to the depth of a crevice or slightly thin of the thickness of a metal membrane 16 is good. Finally the photoresist mask 15 is removed (d). Metal membranes other than a crevice also exfoliate at this time, and a metal membrane 16 remains only in a crevice.

[0008] The Kushigata electrode may be formed as follows. A procedure is shown for the method of forming the Kushigata electrode in drawing 5 later on. After washing the piezo electric crystal single crystal substrate 11 first, the photoresist mask 15 is formed (a). The substrate 11 which formed the photoresist mask 15 next is etched in a fluoric acid system water solution, and a crevice is formed periodically (b). Then, the photoresist mask 15 is removed (c). Next, a metal membrane 16 is formed in the field in which the crevice was formed, with a vacuum deposition method (d). The thickness of a metal membrane 16 has preferably good depth, EQC, or only thick thing of a crevice here. In order to remove metal membranes 16 other than said crevice finally, it is failed by polish (mechanochemical polishing) using an abrasive grain to delete the front face of a metal membrane 16 and the piezo electric crystal single crystal substrate 11 (e). A metal membrane 16 remains only in a crevice according to the above process. With an above-mentioned elastic boundary wave component, although the Kushigata electrode was formed with vacuum deposition, it may use other forming methods, such as sputtering. Moreover, with the gestalt of this operation, in order to use an alkali system solution in hydrophilization processing of a direct junction process, the metal which uses gold as a principal component as an ingredient of the Kushigata electrode was used. When the metal which does not use gold as a principal component also forms a protective coat after the Kushigata electrode formation, the direct junction process in the gestalt of this operation can be performed satisfactory.

[0009] Next, a direct junction process is explained. First, the front face of the piezo electric crystal single crystal substrate (the crevice is formed) 11 which it is going to join directly, and the front face of the piezo electric crystal single crystal substrate 12 are defecated. Then, hydrophilization processing is carried out. By

specifically dipping in an ammonia-hydrogen-peroxide solution, a hydroxyl group comes to adhere to a front face easily, and hydrophilization is carried out. Next, pure water washes enough. Thereby, a hydroxyl group adheres to the front face of two substrates 11 and 12. If said two substrates are piled up in this condition, said two substrates will adsorb mainly by the hydrogen bond of a hydroxyl group. Thereby, the front face of the piezo electric crystal single crystal substrate 11 and the front face of the piezo electric crystal single crystal substrate 12 join together on atomic level, and direct junction structure of both substrates is realized. The above direct junction process is performed in ordinary temperature.

[0010] Although bonding strength sufficient also as [this] is obtained, in order to strengthen bonding strength further, the water constituent falls out from the junction interface gradually by heat-treating from several 10 minutes at the temperature of 100 degrees C or more for several 10 hours with that adsorbed state. In the gestalt of this operation, heat treatment of 10 hours is performed at about 200 degrees C. Association with which oxygen, hydrogen, and a substrate configuration atom are concerned progresses, junction of substrate configuration atoms begins from association of the hydrogen bond subject of a hydroxyl group gradually, and junction is strengthened by this heat treatment. When there are silicon, carbon, and oxygen especially, covalent bond progresses and junction is strengthened.

[0011] The junction structure of atomic level where direct junction does not mind the adhesives between two matter is said. With this operation gestalt, direct junction is chemical bond structure of the atomic level through an oxygen atom which carries out hydrophilization processing and is realized defecation and by carrying out superposition heat treatment in the substrate front face used as a junction interface. Since direct junction is joined in the precision of a crystal lattice, i.e., atomic order, and there is no elastic discontinuity of a junction interface, the propagation loss of the elastic wave in a junction interface is very small. Moreover, since direct junction is used and the junction itself takes place in ordinary temperature, in junction, residual stress is not produced in a substrate.

Moreover, since direct junction is used, maintaining a piezo-electricity elastic property [bulk] unlike a thin film formation process, it is the ingredient combination of arbitration and a compound laminated circuit board is obtained by the crystal orientation of arbitration. For this reason, it can respond to the elastic boundary wave component of various applications. Moreover, since bulk substrates are joined, membrane formation time amount is not needed like the film, but an elastic boundary wave component can be produced within practical time amount. Moreover, an electrode layer can be formed only in the crevice established in one substrate, and it makes it possible to embed the Kushigata electrode easily by direct junction at an interface. Moreover, the same effectiveness as an above-mentioned elastic boundary wave component is acquired also with the structure which transposed one substrate of the piezo electric crystal single crystal substrates 11 and 12 to the low-fever expansion coefficient glass substrate or the quartz substrate. About this structure, since a low-fever expansion coefficient glass substrate or a quartz substrate is the ingredient which can etch easily, a crevice tends [furthermore] to form it. It is effective in furthermore the temperature dependence of the propagation property of an elastic wave being improved. Moreover, the same effectiveness as said elastic boundary wave component is acquired also with the structure which transposed one substrate of the piezo electric crystal single crystal substrates 11 and 12 to the silicon substrate. Furthermore about this structure, there is effectiveness of the miniaturization of the device by compound-izing with a semiconductor circuit. As mentioned above, according to the gestalt of this operation, it excels in a piezo-electric property and elasticity at a bulk substrate and an EQC, and the degree of freedom of a design can offer a large elastic boundary wave component. In addition, although the crevice was formed in the piezo electric crystal substrate 11 and the Kushigata electrode was formed with the gestalt of this operation, even if it forms a crevice in the piezo electric crystal substrate 12 of another side and forms the Kushigata electrode, it cannot be overemphasized that the same effectiveness is acquired.

[0012] (Gestalt 2 of operation) Drawing 6 is 1 section notching perspective view of the gestalt of operation of the 2nd of the elastic boundary wave component of this invention, and drawing 7 is a sectional view in the a-a' section of drawing 6 . As shown in drawing 6 and drawing 7 R> 7, the elastic boundary wave component is constituted using the piezo electric crystal single crystal substrate 41, the piezo electric crystal single crystal substrate 42, the piezo electric crystal single crystal substrate 43, the Kushigata electrodes 44 and 45, 44', and 45'. The crevice is formed in the plane of composition of the piezo electric crystal single crystal substrate 41 with the predetermined period, and said Kushigata electrode is formed in said crevice. Drawing 3 shows the piezo electric crystal single crystal substrate 41, the piezo electric crystal single crystal substrate 42, and the piezo electric crystal single crystal substrate 43, respectively, and the piezo electric crystal single crystal substrate 41, the piezo electric crystal single crystal substrate 42, and the piezo electric crystal single crystal substrate 43 of each other are laminated by direct junction. In addition, although at least one substrate of three substrates 41, 42, and 43 should just be a piezo electric crystal single crystal, with this operation gestalt, all of three substrates are single crystal substrates. When operating as an elastic boundary wave component, by impressing an alternating electric field to the Kushigata electrodes 44 and 45, an elastic boundary wave is excited and said elastic boundary wave spreads in accordance with said interface. Here, if thickness of the 2nd piezo electric crystal single crystal substrate 42 is made thin, unlike the elastic boundary wave component of the 1st operation gestalt, an elastic boundary wave will mainly spread the inside of the piezo electric crystal single crystal substrate 42. An elastic boundary wave is again changed into an electrical signal by Kushigata electrode 44' and 45'. Although the gestalt of this operation shows the basic configuration of the elastic boundary wave component which used the Kushigata electrode, in actually making it a filter and a resonator, it changes the number and configuration of the Kushigata electrode like the 1st operation gestalt if needed.

[0013] By the way, formation of the Kushigata electrode and direct junction are large, and the manufacture process of an elastic boundary wave component is divided into two processes. First, the method of forming the Kushigata electrode is explained. A procedure is shown for the method of forming the Kushigata electrode in drawing 9 later on. The method of forming the future Kushigata electrodes is the same as that of the 1st operation gestalt. After washing the piezo electric crystal single crystal substrate 41 first, the photoresist mask 46 is formed (a). Next, the substrate side in which the photoresist mask 46 was formed is etched in a fluoric acid system water solution, and a crevice is formed periodically (b). Next, a metal membrane 47 is formed in the field in which said crevice was formed, with a vacuum deposition method (c). The desirable thing equivalent to the depth of said crevice or slightly thin of the thickness of a metal membrane 47 is good here. Finally the photoresist mask 46 is removed (d). At this time, metal membranes other than said crevice also exfoliate, and a metal membrane 47 remains only in said crevice.
[0014] Moreover, the Kushigata electrode may be formed as follows. A procedure is shown for the method of forming the Kushigata electrode in drawing 10 later on. After washing the piezo electric crystal single crystal substrate 41 first, the photoresist mask 46 is formed (a). The substrate which formed the photoresist mask 46 next is etched in a fluoric acid system water solution, and a crevice is formed periodically (b). Then, the photoresist mask 46 is removed (c). Next, a metal membrane 47 is formed in the field in which the crevice was formed, with a vacuum deposition method (d). The thickness of a metal membrane 47 has preferably good depth, EQC, or only thick thing of a crevice. In order to remove metal membranes 47 other than a crevice finally, it is failed by polish (mechanochemical polishing) using an abrasive grain to delete the front face of a metal membrane 47 and the piezo electric crystal single crystal substrate 41 (e). A metal membrane 47 remains only in said crevice according to the above process. With an above-mentioned elastic boundary wave component, although the Kushigata electrode was formed with vacuum deposition, it may use other

forming methods, such as sputtering. Moreover, with the gestalt of this operation, in order to use an alkali system solution in hydrophilization processing of a direct junction process, the metal which uses gold as a principal component as an ingredient of the Kushigata electrode was used. When the metal which does not use gold as a principal component also forms a protective coat after the Kushigata electrode formation, the direct junction process in the gestalt of this operation can be performed satisfactory.

[0015] Next, a direct junction process is explained. The front face of the piezo electric crystal single crystal substrate (a crevice is formed) 41 which it is going to join directly first and the front face of the piezo electric crystal single crystal substrate 42, and the front face of the piezo electric crystal single crystal substrate 43 are defecated. Then, hydrophilization processing is carried out. By specifically dipping in an ammonia-hydrogen-peroxide solution, a hydroxyl group comes to adhere to a front face easily, and hydrophilization is carried out. Next, pure water washes enough. Thereby, a hydroxyl group adheres to the front face of three substrates 41-43. If three substrates 41-43 are piled up in this condition, three substrates 41-43 will adsorb mainly by the hydrogen bond of a hydroxyl group. The above direct junction process is performed in ordinary temperature.

[0016] Although bonding strength sufficient also as [this] is obtained, in order to strengthen bonding strength further, the water constituent falls out from the junction interface gradually by heat-treating from several 10 minutes at the temperature of 100 degrees C or more for several 10 hours with that adsorbed state. In the gestalt of this operation, heat treatment of 10 hours is performed at about 200 degrees C. Association with which oxygen, hydrogen, and a substrate configuration atom are concerned progresses, junction of substrate configuration atoms begins from association of the hydrogen bond subject of a hydroxyl group gradually, and junction is strengthened by this heat treatment. When there are silicon, carbon, and oxygen especially, covalent bond progresses and junction is strengthened.

[0017] Since direct junction is joined in the precision of a crystal lattice, i.e.,

atomic order, and there is no elastic discontinuity of a junction interface, the propagation loss of the elastic wave in a junction interface is very small. Moreover, if direct junction is used, since the junction itself will take place in ordinary temperature, in junction, residual stress is not produced in a substrate. Moreover, if direct junction is used, since it is the ingredient combination of arbitration and a compound laminated circuit board is obtained [and] by the crystal orientation of arbitration, maintaining a piezo-electricity elastic property [bulk] unlike a thin film formation process, it can respond to the elastic boundary wave component of various applications. Moreover, since bulk substrates are joined, time amount for depositing the film is not needed, but an elastic boundary wave component can be created within practical time amount. Moreover, with this operation gestalt, an electrode layer can be formed only in the crevice established in one substrate, and it makes it possible to embed the Kushigata electrode easily by direct junction at an interface. Moreover, the same effectiveness as said elastic boundary wave component is acquired also with the structure which transposed both the piezo electric crystal single crystal substrates 41 and 43 in this operation gestalt to the low-fever expansion coefficient glass substrate. It is effective in becoming easy to form a crevice in said low-fever expansion coefficient glass substrate, and furthermore, the temperature dependence of the propagation property of an elastic wave being improved about this structure. Moreover, the same effectiveness as said elastic boundary wave component is acquired also with the structure which transposed the piezo electric crystal single crystal substrate 42 in this operation gestalt to the quartz. Furthermore about this structure, it is effective in the temperature dependence of the propagation property of an elastic wave being improved. As mentioned above, according to this operation gestalt, it excels in a piezo-electric property and elasticity at a bulk substrate and an EQC, and the degree of freedom of a design can offer a large elastic boundary wave component.

[0018] In addition, although the crevice was formed in the piezo electric crystal substrate 41 with this operation gestalt, even if it forms a crevice in the piezo

electric crystal substrate 42 or the piezo electric crystal substrate 43, it cannot be overemphasized that the same effectiveness is acquired. Moreover, although the crevice was formed only in the piezo electric crystal substrate 41, it may combine also with the interface of other substrates 42 or 43, and a crevice may be formed. Moreover, although three substrates were collectively joined directly with this operation gestalt, the same effectiveness is acquired even if it joins the one remaining substrate to a substrate [finishing / junction] directly, after joining two substrates directly.

[0019]

[Effect of the Invention] Since the 1st elastic boundary wave component of this invention consists of direct junction structure of the 1st substrate and the 2nd substrate, an elastic wave mainly spreads the junction interface of said 1st substrate and said 2nd substrate. Moreover, since the 2nd elastic boundary wave component of this invention consists of direct junction structure of the 1st - the 3rd substrate, an elastic wave mainly spreads said 3rd substrate. Since an interface consists of direct junction structure, it excels in a piezo-electricity elastic property, and an elastic boundary wave component with the large degree of freedom of a design can be realized.

[Translation done.]

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

[Drawing 1] 1 section notching perspective view of the elastic boundary wave component of the gestalt of operation of the 1st of this invention

[Drawing 2] The sectional view of the aforementioned elastic boundary wave component

[Drawing 3] The perspective view of a piezo electric crystal single crystal substrate and a piezo electric crystal single crystal substrate

[Drawing 4] The explanatory view of the 1st electrode forming method of the aforementioned elastic boundary wave component

[Drawing 5] The explanatory view of the 2nd electrode forming method of the aforementioned elastic boundary wave component

[Drawing 6] 1 section notching perspective view of the elastic boundary wave component of the gestalt of operation of the 2nd of this invention

[Drawing 7] The sectional view of the aforementioned elastic boundary wave component

[Drawing 8] The perspective view of a piezo electric crystal single crystal substrate and a piezo electric crystal single crystal substrate

[Drawing 9] The explanatory view of the 1st electrode forming method of the aforementioned elastic boundary wave component

[Drawing 10] The explanatory view of the 2nd electrode forming method of the aforementioned elastic boundary wave component

[Drawing 11] The sectional view of the conventional elastic boundary wave component

[Description of Notations]

11 12 Piezo electric crystal single crystal substrate

13, 13', 14, 14' Kushigata electrode

16 Metal Layer

41, 42, 43 Piezo electric crystal single crystal substrate

44, 44', 45, 45' Kushigata electrode

47 Metal Layer

[Translation done.]

* NOTICES *

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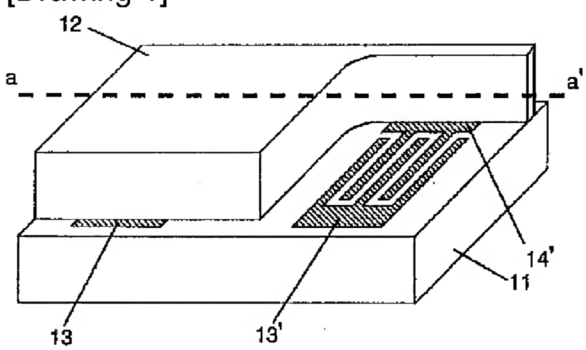
1.This document has been translated by computer. So the translation may not reflect the original precisely.

2.**** shows the word which can not be translated.

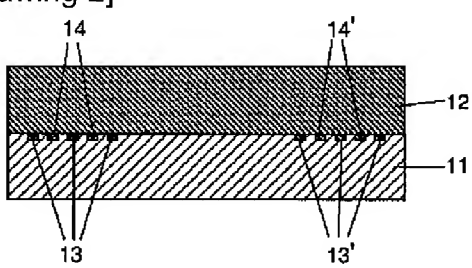
3.In the drawings, any words are not translated.

DRAWINGS

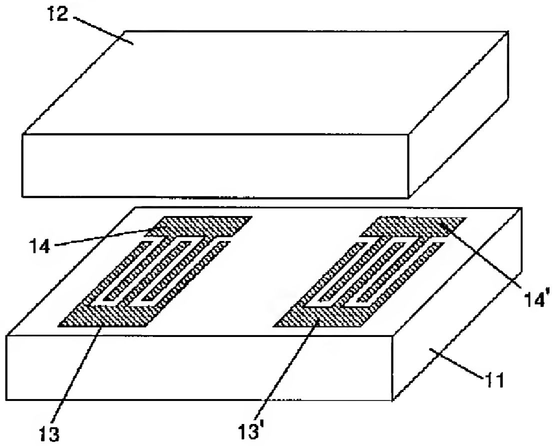
[Drawing 1]



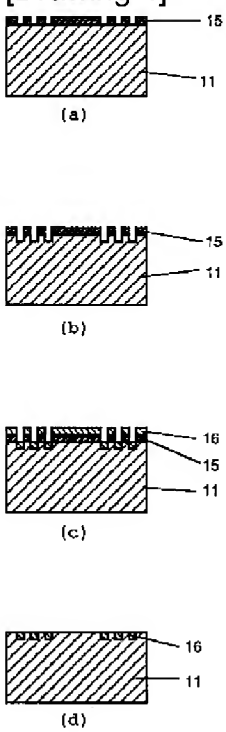
[Drawing 2]



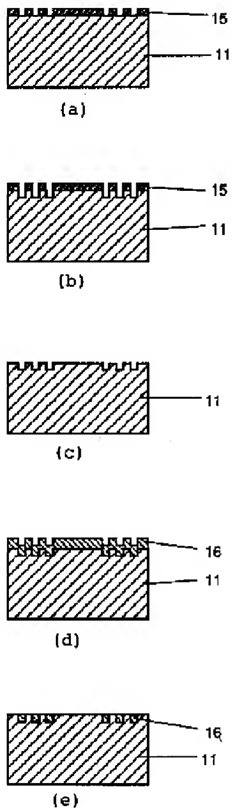
[Drawing 3]



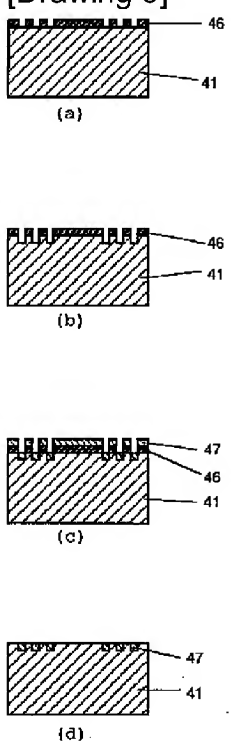
[Drawing 4]



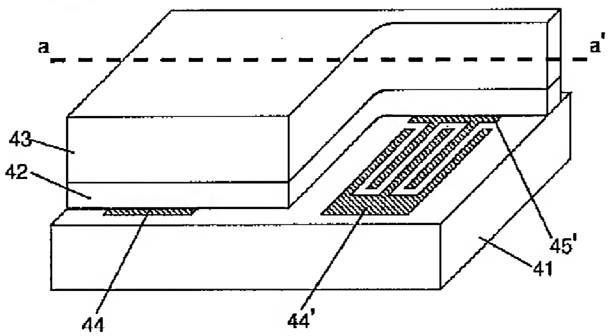
[Drawing 5]



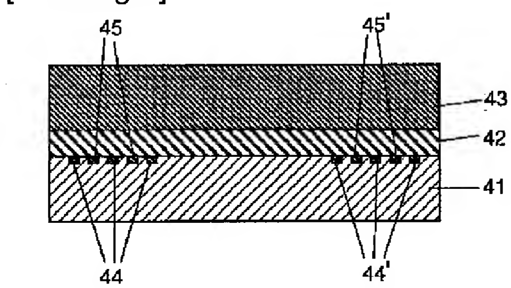
[Drawing 9]



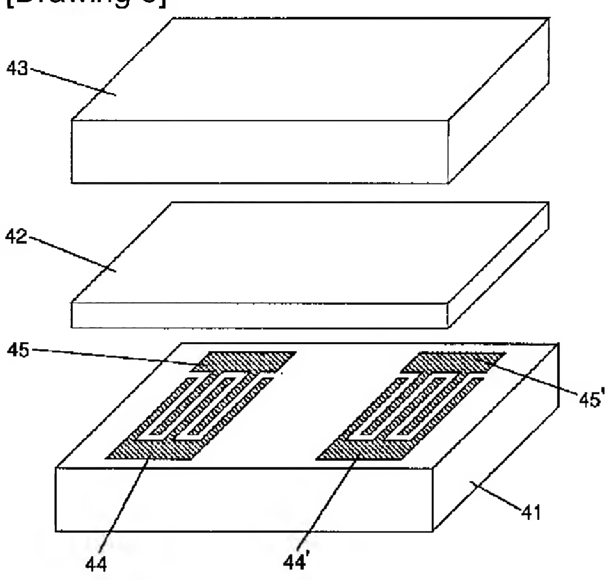
[Drawing 6]



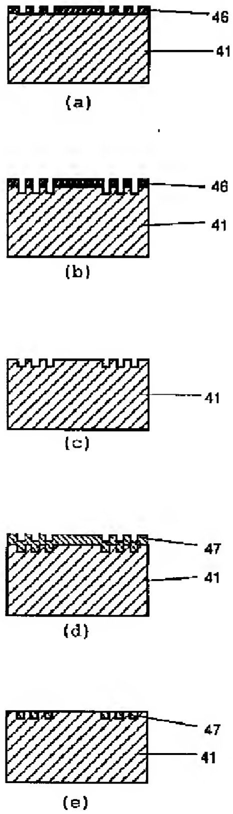
[Drawing 7]



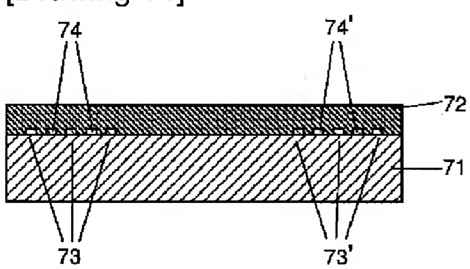
[Drawing 8]



[Drawing 10]



[Drawing 11]



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Ｃ

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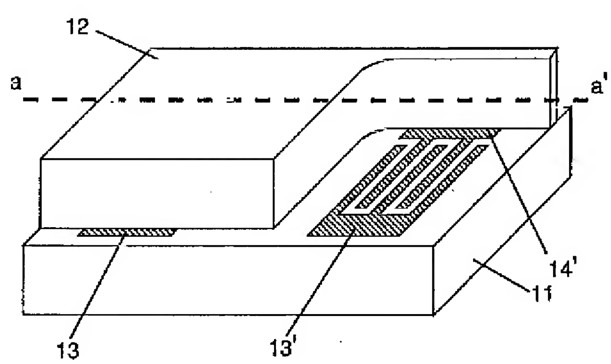
最終頁に続く

(54)【発明の名称】　弾性境界波素子

(57)【要約】
【課題】　フィルタや共振子などに用いる圧電特性に優れ、設計の自由度が大きい弾性境界波素子を提供する。
【解決手段】　弾性境界波素子は、２枚の圧電性基板の直接接合構造、または、３枚の圧電性基板の直接接合構造からなる。ここで、前記の基板の少なくとも一枚の基板が圧電体単結晶であり、かつ、少なくとも一方の基板の一方主面上に櫛形電極が形成される。櫛形電極が形成された面が界面となるように前記基板を原子レベルで直接接合する。以上の構成によって、圧電特性に優れ、設計の自由度が大きい弾性境界波素子が得られる。



【特許請求の範囲】

【請求項１】　第１の基板と、第２の基板と、弾性波を励振するための櫛形電極とからなり、前記第１および第２の基板の少なくとも一方の基板が圧電体単結晶であり、かつ、少なくとも一方の基板の一方主面上に周期的に形成された凹部に前記櫛形電極が形成され、前記櫛形電極が形成された面が界面となるように前記第１および前記第２の基板の接合界面となる基板表面を清浄化、親水化処理して、重ね合わせ熱処理することによって原子レベルで直接接合されることを特徴とする弾性境界波素子。

【請求項２】　前記のすべての基板が圧電体単結晶であることを特徴とする請求項１に記載の弾性境界波素子。

【請求項３】　前記の第１と第２の基板のうち少なくとも１つの基板が、珪素、酸化珪素および酸化珪素を主成分とする物質から選ばれることを特徴とする請求項１または２に記載の弾性境界波素子。

【請求項４】　第１の基板と、第２の基板と、前記第１の基板と第２の基板によって挟まれた第３の基板と、弾性波を励振するための櫛形電極からなり、前記第１、第２および第３の基板の少なくとも１つの基板が圧電体単結晶であり、かつ、少なくとも１つの基板の一方主面上に形成された凹部に前記櫛形電極が形成され、前記櫛形電極が形成された面が少なくとも１つの界面となるように前記第１、第２および第３の基板の接合界面となる基板表面を清浄化、親水化処理して、重ね合わせ熱処理することによって原子レベルで直接接合されることを特徴とする弾性境界波素子。

【請求項５】　前記のすべての基板が圧電体単結晶であることを特徴とする請求項４に記載の弾性境界波素子。

【請求項６】　前記の第１、第２および第３の基板のうち少なくとも１つの基板が、珪素、酸化珪素および酸化珪素を主成分とする物質から選ばれることを特徴とする請求項４または５に記載の弾性境界波素子。

【請求項７】　櫛形電極が金を主成分とする合金であることを特徴とする請求項１から６のいずれかに記載の弾性境界波素子。

【請求項８】　櫛形電極に保護層が形成されたことを特徴とする請求項１から７のいずれかに記載の弾性境界波素子。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、フィルタや共振子などに用いる弾性境界波素子に関するものである。

【０００２】

【従来の技術】近年、移動体通信技術の進歩発展により、通信機器の小型、軽量、高性能化が進んでいる。これらの機器には必ず発振器や高周波フィルタが必要であり、これらの発振器や高周波フィルタに対しても小型、軽量、高性能化が求められている。従来よりこれらの発振器や高周波フィルタには弾性表面波素子が広く用いられてきた。弾性表面波素子は、弾性波が主に固体表面を伝搬するデバイスである。したがって固体表面およびその近傍の状態が弾性表面波の伝搬特性に大きく影響を及ぼす。具体的には弾性波が伝搬する固体表面近傍のガス、水蒸気などが影響を与える。したがって弾性波が伝搬する基板表面に空間を保持する必要があり、たとえば弾性表面波素子をパッケージに入れ不活性ガスを充填して封止を行なっていた。このように弾性表面波素子にはパッケージが必要であり、発振器や高周波フィルタの大きさはパッケージの大きさで決まる。そのため発振器や高周波フィルタの小型化、軽量化には限界があった。

【０００３】上記の問題を解決するものとして弾性境界波素子がある。弾性境界波素子は、２つの固体を接合させた境界面にエネルギーを集中させて、弾性波が主に接合界面を伝搬するデバイスである。弾性境界波素子は、境界面が露出していないためパッケージが不要であり、そのため発振器や高周波フィルタの小型化と軽量化が可能となる。従来の弾性境界波素子、たとえば弾性境界波フィルタや弾性境界波共振子では、圧電基板に櫛形電極を形成したのち非圧電層をスパッタ等の成膜法で形成する。または、非圧電基板に櫛形電極を形成したのち圧電層をスパッタ等の成膜法で形成し、さらに前記圧電層に非圧電層をスパッタ等の方法で形成する。前記電極に交番電界を加えることによって弾性境界波を励振している（日本学術振興会弾性表面波素子技術第１５０委員会第９回研究資料、ｐｐ．１７－２２）。以下に従来の弾性境界波素子について説明する。図１１は、従来の弾性境界波素子を示す。弾性境界波素子は、圧電体基板７１、非圧電体層７２、櫛形電極７３、７４、７３'、７４'を用いて構成される。圧電体基板７１上に櫛形電極７３、７４、７３'、７４'が形成され、電極形成面上にスパッタなどの成膜法により非圧電体層７２が形成される。

【０００４】

【発明が解決しようとする課題】上記の弾性境界波デバイスは、薄膜プロセスを用いて積層構造を形成する。この場合、基板と膜材料の組合せに制限を受ける。たとえば膜材料として圧電体を選ぶとき、圧電特性を出すためには少なくとも結晶方向を一方向にそろえて配向させることが必要であるが、配向させるためには、基板と膜材料の組み合わせがきわめて限定される。また膜の配向方向も限定される。また、スパッタリングなどにより形成した圧電膜は弾性的性質のばらつきが大きく、バルク単結晶に比べて圧電特性が劣る。望ましくはエピタキシャル成長技術により圧電単結晶薄膜を形成するのが好ましいが、エピタキシャル成長ができる基板は限られ、基板と膜材料の組合せはさらに限定される。また、様々な用途の弾性境界波素子に対応するには、任意の基板と圧電体の組合せによる積層構造が求められるが、従来の成膜による方法では組合せが極めて限定される。また、薄膜

プロセスでは基板加熱が必要であるため残留応力が問題となる。具体的には、基板冷却過程において過度に応力が残留した場合に基板を破壊することがある。基板破壊に至らない場合でも、基板に反りが生じ、フォトリソグラフィをプロセスに用いる場合には不具合の原因になる。また、弾性境界波素子には積層基板表面において弾性境界波の変位が実質的になくなる程度の基板厚みが必要であるが、成膜による場合、十分な厚さの膜の堆積には時間がかかり実用上問題があった。また、積層の手段として接着剤を用いた場合には、接着層の薄さには限度があり、さらに、接着層の厚さを均一にすることが難しい。また、接着層において弾性境界波は著しく減衰し、好ましい特性は得られない。また、時間とともに接着層の弾性的性質も変化する。本発明の目的は、任意のバルク基板材料での積層構造を接着層なしに実現し、かつ櫛形電極を界面に形成することを可能とし、特性設計や製造が容易で特性が安定した弾性境界波素子を提供することである。

【０００５】

【課題を解決するための手段】本発明の第１の弾性境界波素子は、第１の基板と、第２の基板と、弾性波を励振するための櫛形電極とからなる。前記第１および第２の基板の少なくとも一方の基板が圧電体単結晶であり、かつ、少なくとも一方の基板の一方主面上に周期的に形成された凹部に前記櫛形電極が形成される。前記櫛形電極が形成された面が界面となるように前記第１および前記第２の基板が直接接合される。直接接合は、接合界面となる基板表面を清浄化、親水化処理して、重ね合わせ熱処理することによる酸素原子を介した原子レベルの接合である。この構造において、弾性波が主として前記第１の基板と前記第２の基板の接合界面を伝搬することを特徴とする。このような構成をとることにより、圧電特性に優れ、設計の自由度が大きい弾性境界波素子を提供できる。また、本発明の第２の弾性境界波素子は、第１の基板と、第２の基板と、前記第１の基板と第２の基板によって挟まれた第３の基板と、弾性波を励振するための櫛形電極からなる。前記第１および第２、第３の基板の少なくとも１つの基板が圧電体単結晶であり、かつ、少なくとも１つの基板の一方主面上に周期的に形成された凹部に前記櫛形電極が形成される。前記第１および第２、第３の基板が、前記櫛形電極が形成された面が界面となるようにして互いに直接接合される。直接接合は、接合界面となる基板表面を清浄化、親水化処理して、重ね合わせ熱処理することによる酸素原子を介した原子レベルの接合である。この構造において、弾性波が主として前記第３の基板を伝搬することを特徴とする。このような構成をとることにより、圧電特性に優れ、設計の自由度が大きい弾性境界波素子を提供できる。また前記すべての基板が圧電体単結晶であってもよい。また前記少なくとも１つの基板が、珪素、酸化珪素および酸化珪素を主成分とする物質から選ばれたものであってもよい。また前記櫛形電極が金を主成分とする合金であってもよい。また前記櫛形電極に保護層が形成されていてもよい。

【０００６】

【発明の実施の形態】以下、本発明の実施の形態について添付の図面を参照しながら詳細に説明する。

（実施の形態１）図１は、本発明の弾性境界波素子の第１の実施の形態の１部切欠斜視図であり、図２は、図１のａ－ａ’部での断面図である。図１と図２に示す弾性境界波素子は、圧電体単結晶基板１１、圧電体単結晶基板１２、櫛形電極１３、１４、１３’、１４’を用いて構成されている。一方の圧電体単結晶基板１１の接合面には凹部が所定の周期で形成されており、前記凹部には櫛形電極１３、１４、１３’、１４’が形成されている。図３は、圧電体単結晶基板１１と圧電体単結晶基板１２をそれぞれ示したものであり、図１と図２に示すデバイスでは、圧電体単結晶基板１１と圧電体単結晶基板１２とが直接接合により、接着剤なしに積層化されている。なお、第１および第２の基板１１、１２の少なくとも一方の基板が圧電体単結晶であればよいが、本実施形態では、両基板とも単結晶基板である。弾性境界波素子としての動作は、櫛形電極１３、１４に交番電界を印加することにより弾性境界波が励振され、両圧電体基板１１、１２の間の界面に沿って弾性境界波が伝搬する。この弾性境界波は櫛形電極１３’、１４’で再び電気信号に変換される。なお、図１と図２には、櫛形電極を用いた弾性境界波の基本構成を示しているが、フィルタや共振子にする場合には、櫛形電極の数や構成を必要に応じて変更する。

【０００７】この弾性境界波素子の製造プロセスは、櫛形電極の形成と直接接合の大きく２つのプロセスに分かれる。まず櫛形電極の形成について説明する。図４に櫛形電極の形成法を手順をおって示す。はじめに圧電体単結晶基板１１を洗浄したのち、フォトレジストマスク１５を形成する（ａ）。次にフォトレジストマスク１５を形成した基板面１１をフッ酸系水溶液でエッチングして周期的に凹部を形成する（ｂ）。次に凹部を形成した面に真空蒸着法によって金属膜１６を形成する（ｃ）。金属膜１６の厚みは、好ましくは凹部の深さと同等もしくはわずかに薄いのが良い。最後にフォトレジストマスク１５を除去する（ｄ）。このとき凹部以外の金属膜も剥離し、凹部のみに金属膜１６が残る。

【０００８】櫛形電極は、以下のように形成しても良い。図５に櫛形電極の形成法を手順をおって示す。はじめに圧電体単結晶基板１１を洗浄したのち、フォトレジストマスク１５を形成する（ａ）。つぎにフォトレジストマスク１５を形成した基板１１をフッ酸系水溶液でエッチングして周期的に凹部を形成する（ｂ）。続いて、フォトレジストマスク１５を除去する（ｃ）。次に凹部

を形成した面に真空蒸着法により金属膜１６を形成する（ｄ）。ここで金属膜１６の厚みは、好ましくは凹部の深さと同等もしくはわずか厚いのが良い。最後に前記凹部以外の金属膜１６を除去するため、砥粒を用いた研磨（メカノケミカル－ポリッシング）によって金属膜１６および圧電体単結晶基板１１の表面を削り落とす（ｅ）。以上のプロセスによって凹部のみに金属膜１６が残る。上述の弾性境界波素子では櫛形電極は真空蒸着により形成したが、スパッタリングなど他の形成法を用いても良い。また、本実施の形態では、直接接合プロセスの親水化処理においてアルカリ系溶液を使用するため、櫛形電極の材料として金を主成分とする金属を使用した。金を主成分とはしない金属でも、櫛形電極形成の後に保護膜を形成することによって、本実施の形態における直接接合プロセスを問題なく行える。

【０００９】次に直接接合プロセスについて説明する。まず、直接接合しようとする圧電体単結晶基板（凹部が形成されている）１１の表面ならびに圧電体単結晶基板１２の表面を清浄化する。続いて親水化処理する。具体的には例えばアンモニアー過酸化水素溶液に浸すことにより、表面に水酸基が容易に付着するようになり親水化される。次に純水で十分洗浄する。これにより２枚の基板１１、１２の表面に水酸基が付着する。この状態で前記２枚の基板を重ね合わせると、主として水酸基の水素結合により前記２枚の基板が吸着する。これにより、圧電体単結晶基板１１の表面ならびに圧電体単結晶基板１２の表面が原子レベルで結合し、両基板の直接接合構造が実現される。以上の直接接合プロセスは常温で行う。

【００１０】このままでも十分な接合強度が得られているが、さらに接合強度を強固にするために、その吸着状態のままで、１００℃以上の温度で数１０分から数１０時間熱処理することにより、接合界面から水構成成分が次第に抜けていく。本実施の形態においては約２００℃で１０時間の熱処理を行っている。この熱処理によって、水酸基の水素結合主体の結合から、酸素や水素、また基板構成原子の関わる結合が進み、基板構成原子同士の接合が徐々に始まり、接合は強化される。特に、珪素や炭素、酸素がある場合、共有結合が進み、接合は強化される。

【００１１】直接接合は、２つの物質の間の、接着剤を介さない原子レベルの接合構造をいう。本実施形態では、直接接合は、接合界面となる基板表面を清浄化、親水化処理して、重ね合わせ熱処理することにより実現される、酸素原子を介した原子レベルの化学結合構造である。直接接合は、結晶格子すなわち原子オーダーの精度で接合されていることから、接合界面の弾性的な不連続はないため、接合界面における弾性波の伝搬損失は極めて小さい。また、直接接合を用いるので、接合自体は常温で起こるため、接合において基板に残留応力は生じない。また、直接接合を用いるので、薄膜形成プロセスとは異なり、バルクの圧電的、弾性的性質を保ったまま、また任意の材料組合せで、かつ任意の結晶方位で複合積層基板が得られる。このため、様々な用途の弾性境界波素子に対応できる。また、バルク基板どうしを接合しているため、膜のように成膜時間を必要とせず、実用的な時間内で弾性境界波素子を作製できる。また、一方の基板に設けた凹部内にのみ電極膜を形成することができ、直接接合によって界面に櫛形電極を容易に埋め込むことを可能にしている。また、圧電体単結晶基板１１、１２のいずれか一方の基板を低熱膨張率ガラス基板または石英基板に置き換えた構造でも、上述の弾性境界波素子と同様の効果が得られる。さらにこの構造については、低熱膨張率ガラス基板または石英基板は、エッチングが容易に行える材料であるため凹部が形成しやすい。さらに弾性波の伝搬特性の温度依存性が改善される効果がある。また、圧電体単結晶基板１１、１２のいずれか一方の基板を珪素基板に置き換えた構造でも、前記弾性境界波素子と同様の効果が得られる。さらにこの構造については、半導体回路との複合化によるデバイスの小型化という効果がある。以上のように、本実施の形態によれば、バルク基板と同等に圧電特性、弾性特性に優れ、設計の自由度が大きい弾性境界波素子を提供できる。なお、本実施の形態では圧電体基板１１に凹部を形成し櫛形電極を形成したが、他方の圧電体基板１２に凹部を形成し櫛形電極を形成しても同様の効果が得られるのは言うまでもない。

【００１２】（実施の形態２）図６は、本発明の弾性境界波素子の第２の実施の形態の１部切欠斜視図であり、図７は、図６のａ－ａ'部での断面図である。図６と図７に示すように、弾性境界波素子は、圧電体単結晶基板４１、圧電体単結晶基板４２、圧電体単結晶基板４３、櫛形電極４４、４５、４４'、４５'を用いて構成されている。圧電体単結晶基板４１の接合面には所定の周期で凹部が形成されており、前記凹部には前記櫛形電極が形成されている。図３は、圧電体単結晶基板４１、圧電体単結晶基板４２および圧電体単結晶基板４３をそれぞれ示したものであり、圧電体単結晶基板４１、圧電体単結晶基板４２および圧電体単結晶基板４３は互いに直接接合により積層化されている。なお、３枚の基板４１、４２、４３の少なくとも１枚の基板が圧電体単結晶であればよいが、本実施形態では、３枚の基板がすべて単結晶基板である。弾性境界波素子として動作するとき、櫛形電極４４、４５に交番電界を印加することにより弾性境界波が励振され、前記界面に沿って前記弾性境界波が伝搬する。ここで、第２の圧電体単結晶基板４２の厚さを薄くすると、第１の実施形態の弾性境界波素子と異なり、弾性境界波は、主に圧電体単結晶基板４２内を伝搬する。弾性境界波は櫛形電極４４'、４５'で再び電気信号に変換される。この実施の形態では、櫛形電極を用いた弾性境界波素子の基本構成を示しているが、第１の実

施形態と同様に、実際にフィルタや共振子にする場合には、櫛形電極の数や構成を必要に応じて変更する。

【0013】ところで弾性境界波素子の製造プロセスは、櫛形電極の形成と直接接合の大きく２つのプロセスに分かれる。まず、櫛形電極の形成法について説明する。図９に櫛形電極の形成法を手順をおって示す。以後の櫛形電極の形成法は第１の実施形態と同様である。はじめに圧電体単結晶基板４１を洗浄したのち、フォトレジストマスク４６を形成する（ａ）。次にフォトレジストマスク４６を形成した基板面をフッ酸系水溶液でエッチングして周期的に凹部を形成する（ｂ）。次に前記凹部を形成した面に真空蒸着法によって金属膜４７を形成する（ｃ）。ここで金属膜４７の厚みは、好ましくは前記凹部の深さと同等もしくはわずかに薄いのが良い。最後にフォトレジストマスク４６を除去する（ｄ）。このとき前記凹部以外の金属膜も剥離し、前記凹部のみに金属膜４７が残る。

【0014】また、櫛形電極は、以下のように形成しても良い。図１０に櫛形電極の形成法を手順をおって示す。はじめに圧電体単結晶基板４１を洗浄したのち、フォトレジストマスク４６を形成する（ａ）。つぎにフォトレジストマスク４６を形成した基板をフッ酸系水溶液でエッチングして周期的に凹部を形成する（ｂ）。続いて、フォトレジストマスク４６を除去する（ｃ）。次に凹部を形成した面に真空蒸着法により金属膜４７を形成する（ｄ）。金属膜４７の厚みは、好ましくは凹部の深さと同等もしくはわずか厚いのが良い。最後に凹部以外の金属膜４７を除去するため、砥粒を用いた研磨（メカノケミカルーポリッシング）によって金属膜４７および圧電体単結晶基板４１の表面を削り落とす（ｅ）。以上のプロセスによって前記凹部のみに金属膜４７が残る。上述の弾性境界波素子では櫛形電極は真空蒸着により形成したが、スパッタリングなど他の形成法を用いても良い。また、本実施の形態では、直接接合プロセスの親水化処理においてアルカリ系溶液を使用するため、櫛形電極の材料として金を主成分とする金属を使用した。金を主成分とはしない金属でも、櫛形電極形成の後に保護膜を形成することによって、本実施の形態における直接接合プロセスを問題なく行える。

【0015】次に直接接合プロセスについて説明する。まず直接接合しようとする圧電体単結晶基板（凹部が形成される）４１の表面ならびに圧電体単結晶基板４２の表面、圧電体単結晶基板４３の表面を清浄化する。続いて親水化処理する。具体的には例えばアンモニア-過酸化水素溶液に浸すことにより、表面に水酸基が容易に付着するようになり親水化される。次に純水で十分洗浄する。これにより３枚の基板４１～４３の表面に水酸基が付着する。この状態で３枚の基板４１～４３を重ね合わせると、主として水酸基の水素結合により３枚の基板４１～４３が吸着する。以上の直接接合プロセスは常温で行う。

【0016】このままでも十分な接合強度が得られているが、さらに接合強度を強固にするために、その吸着状態のままで、１００℃以上の温度で数１０分から数１０時間熱処理することにより、接合界面から水構成成分が次第に抜けていく。本実施の形態においては約２００℃で１０時間の熱処理を行っている。この熱処理によって、水酸基の水素結合主体の結合から、酸素や水素、また基板構成原子の関わる結合が進み、基板構成原子同士の接合が徐々に始まり、接合は強化される。特に、珪素や炭素、酸素がある場合、共有結合が進み、接合は強化される。

【0017】直接接合は、結晶格子すなわち原子オーダーの精度で接合されていることから、接合界面の弾性的な不連続はないため、接合界面における弾性波の伝搬損失は極めて小さい。また、直接接合を用いれば、接合自体は常温で起こるため、接合において基板に残留応力は生じない。また、直接接合を用いると、薄膜形成プロセスとは異なり、バルクの圧電的、弾性的性質を保ったまま、また任意の材料組合せで、かつ任意の結晶方位で複合積層基板が得られるため、様々な用途の弾性境界波素子に対応できる。また、バルク基板どうしを接合しているため、膜を堆積するための時間を必要とせず、実用的な時間内で弾性境界波素子を作成できる。また、本実施形態では一方の基板に設けた凹部内にのみ電極膜を形成することができ、直接接合によって界面に櫛形電極を容易に埋め込むことを可能にしている。また、本実施形態における圧電体単結晶基板４１、４３をともに低熱膨張率ガラス基板に置き換えた構造でも前記弾性境界波素子と同様の効果が得られる。さらにこの構造については、前記低熱膨張率ガラス基板に凹部を形成しやすくなり、また弾性波の伝搬特性の温度依存性が改善される効果がある。また、本実施形態における圧電体単結晶基板４２を石英に置き換えた構造でも前記弾性境界波素子と同様の効果が得られる。さらにこの構造については、弾性波の伝搬特性の温度依存性が改善される効果がある。以上のように本実施形態によれば、バルク基板と同等に圧電特性、弾性特性に優れ、設計の自由度が大きい弾性境界波素子を提供できる。

【0018】なお、本実施形態では圧電体基板４１に凹部を形成したが、圧電体基板４２もしくは圧電体基板４３に凹部を形成しても同様の効果が得られるのは言うまでもない。また圧電体基板４１のみに凹部を形成したが、他の基板４２または４３の界面にも併せて凹部を形成しても良い。また、本実施形態では３枚の基板を一括して直接接合したが、２枚の基板を直接接合したのち残りの１枚の基板を接合済みの基板に直接接合しても同様の効果が得られる。

【0019】

【発明の効果】本発明の第１の弾性境界波素子は、第１

の基板と第２の基板の直接接合構造からなるので、弾性波が主として前記第１の基板と前記第２の基板の接合界面を伝搬する。また、本発明の第２の弾性境界波素子は、第１～第３の基板の直接接合構造からなるので、弾性波が主として前記第３の基板を伝搬する。界面が直接接合構造からなるので、圧電的、弾性的性質に優れ、また設計の自由度の大きい弾性境界波素子を実現できる。

【図面の簡単な説明】

【図１】本発明の第１の実施の形態の弾性境界波素子の１部切欠斜視図

【図２】前記の弾性境界波素子の断面図

【図３】圧電体単結晶基板と圧電体単結晶基板の斜視図

【図４】前記の弾性境界波素子の第１の電極形成法の説明図

【図５】前記の弾性境界波素子の第２の電極形成法の説明図

【図６】本発明の第２の実施の形態の弾性境界波素子の１部切欠斜視図

【図７】前記の弾性境界波素子の断面図

【図８】圧電体単結晶基板と圧電体単結晶基板の斜視図

【図９】前記の弾性境界波素子の第１の電極形成法の説明図

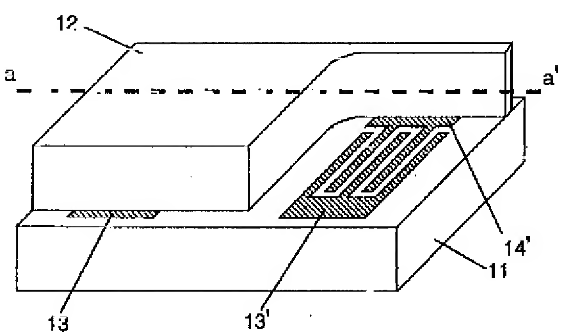
【図１０】前記の弾性境界波素子の第２の電極形成法の説明図

【図１１】従来の弾性境界波素子の断面図

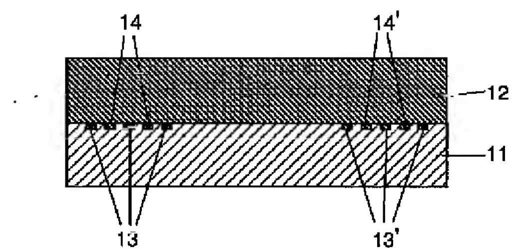
【符号の説明】

１１、１２　圧電体単結晶基板
１３、１３’、１４、１４’　櫛形電極
１６　金属層
４１、４２、４３　圧電体単結晶基板
４４、４４’、４５、４５’　櫛形電極
４７　金属層

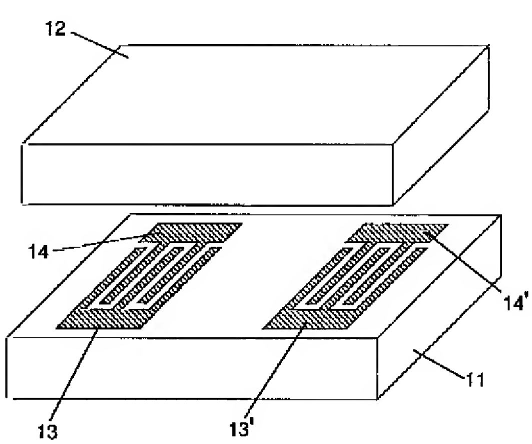
【図１】



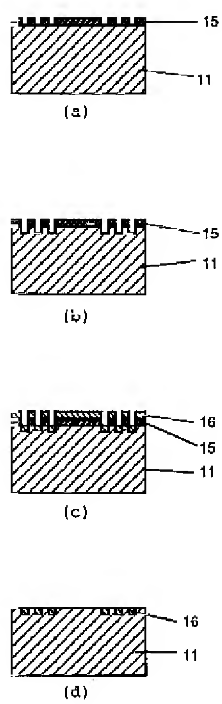
【図２】



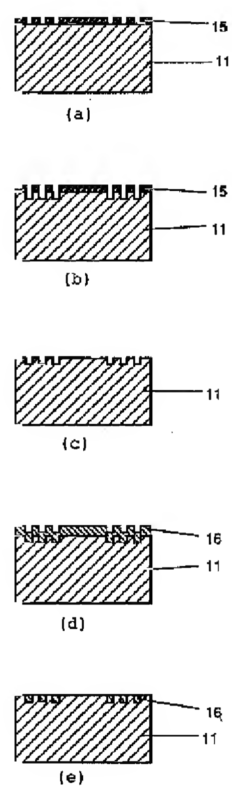
【図３】



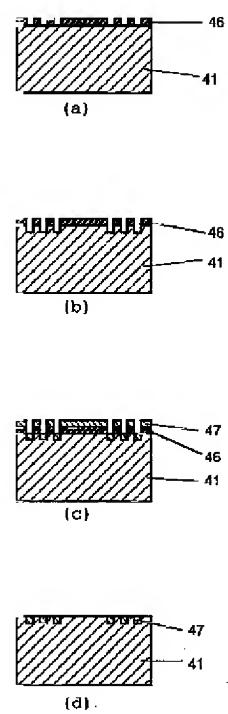
【図４】



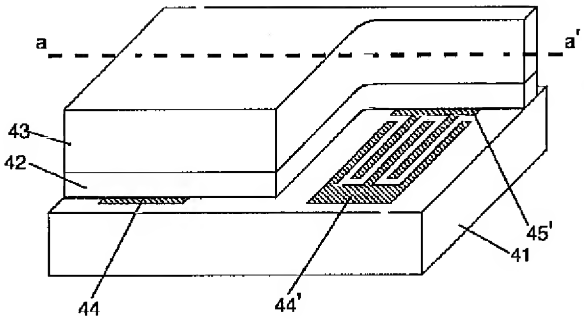
【図５】



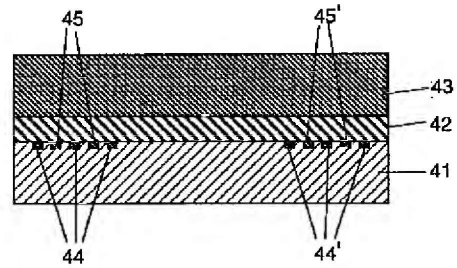
【図９】



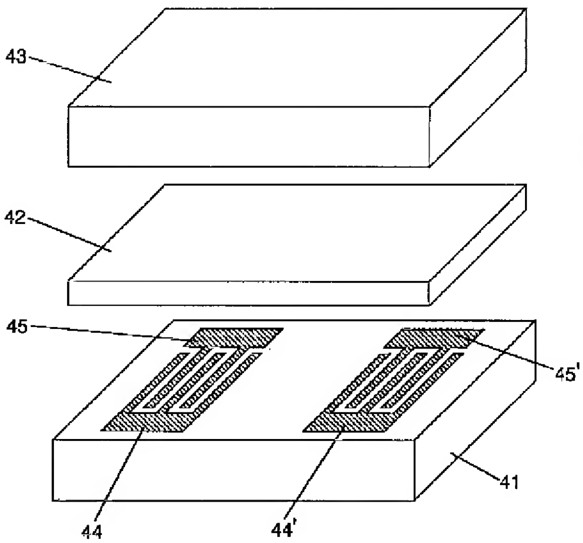
【図６】



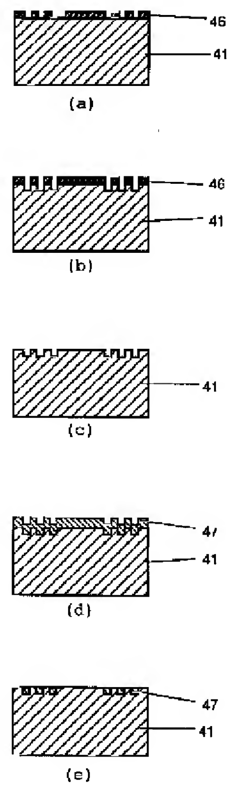
【図７】



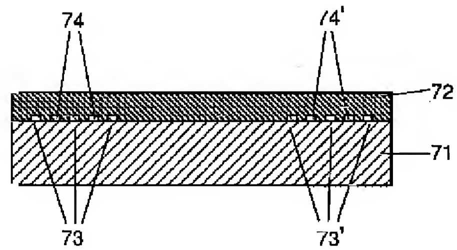
【図８】



【図１０】



【図１１】



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